SOIL MOISTURE TENSION VARIATION ON CUTOVERS IN SOUTHWESTERN OREGON

William E. Hallin

PACIFIC NORTHWEST
Forest and Range Experiment Station
U. S. Department of Agriculture
Portland, Oregon

U. S. D. A. FOREST SERVICE RESEARCH PAPER PNW-58

1968

CONTENTS

INTRODUCTION

Soil moisture stress is often the cause of seedling mortality in regenerating mixed-conifer forests of southwestern Oregon. Also, moisture status is an important consideration in stand manipulation or fertilization for increasing timber production.

The tension at which moisture is held by the soil provides the best means for comparing moisture status of different kinds of soils and for indicating the availability of moisture at a particular location. For example, 15 atmospheres is considered to be the soil moisture tension at the permanent wilting point of plants (Richards and Weaver 1943; Shaw 1952, pp. 156-157),[1] and 3 atmospheres is the soil moisture tension at which the growth of some trees stops (Zahner and Whitmore 1960).

Soil moisture tension of field samples is usually determined by referring actual soil moisture content to a curve of soil moisture retention over tension constructed for the soil in question. The purposes of this paper are: (1) to report characteristics of soil moisture retention over tension curves for several southwestern Oregon forest soils; (2) to report variation in soil moisture at 15 atmospheres of tension in relation to parent material, aspect, depth, clay content, and between points 10 feet apart; (3) to compare soil moisture tension on cutovers with and without vegetation during the driest part of the growing season. Soil texture is also discussed to characterize the study soils.

Although this paper is written primarily for researchers concerned with forest soil moisture, practicing foresters may be particularly interested in the section, "Soil Moisture Tension Attained With and Without Vegetation," pages 13 to 15, and the discussion concerning the effects of vegetation on soil moisture tension, pages 16 and 17.

[1] *Names and dates in parentheses refer to Literature Cited, p. 18.*

METHODS

Soil samples were collected at three depths, at 69 sampling points, for a total of 207 sampling positions. At each position, two samples were collected during the driest portion of the summer before the first late summer rain. One sample was used for determining field moisture content and the other for determining soil moisture retention over tension curves and for textural analysis.

Study Areas

Three areas were chosen for study: Calf Creek, South Umpqua, and Dead Indian (fig. 1).

Calf Creek. — The first area, about 2 acres, is in a clearcut in the Calf Creek drainage of the North Umpqua River at latitude 43°16′ and longitude 122°36′. Elevation is 3,000 feet. Aspect varies from east to northeast and slope from 0 to about 20 percent. The soil is a loam at 6-inch depth and typically a clay loam at 18- and 36-inch depths. It is probably in the tentative Freezeout[2] series. Soil samples were collected at distances of ½, 1, 2, 3, 4, and 5 chains along four lines, approximately 1 chain apart, extending to the north into the clearcut from the east and west timber edges for a total of 24 sampling points. This study was originally designed to measure the effect of distance from clearcut edge on soil moisture content. However, unusually abundant rainfall during the summer of 1964 masked any effect this distance may have had on soil moisture levels. Data from this area are used primarily to show variation in soil moisture retention over tension curves and in soil texture within a small area.

South Umpqua. — The second area is in the South Umpqua drainage extending 11 miles east and west and 9 miles north and south, from longitude 122°34′ to 122°49′ and latitude 43° to 43°7′. The northernmost samples were collected 10 miles due south of the Calf Creek area. Elevations ranged from 1,600 to 3,200 feet. Investigations included: (1) comparisons of soil moisture-tension relationships for soils derived from basaltic and rhyolitic parent material; (2) measurement of the effect of competing vegetation in cutovers on soil moisture tension; (3) comparisons of soil moisture-tension curves for points 10 feet apart; and (4) determination of relationship between clay content and characteristics of soil moisture retention over tension curves.

Sampling locations with three replications were selected on north-slope, south-slope, and level areas on clearcuts for each of the two parent materials (basalt and rhyolite), making a total of 18 locations. Clearcuts were chosen where slash had been burned several years previously but where vegetation was still predominantly herbaceous or grass species rather than shrubs. At each location, two stakes were driven 10 feet apart along a contour, thus making a total of 36 sampling points. One stake was randomly selected as the center of a 10- by 10-foot area from which all vegetation was removed with a hoe and mattock. Vegetation was left around the other stake. Vegetation was removed in late May and early June and again in late June.

North and south aspect plots varied from 45- to 90-percent slope, and level plots from 0

[2] *Richlen, E. M. Soil survey report of South Umpqua area of Umpqua National Forest. In-Service report, Region 6, U. S. Forest Serv. 1963.*

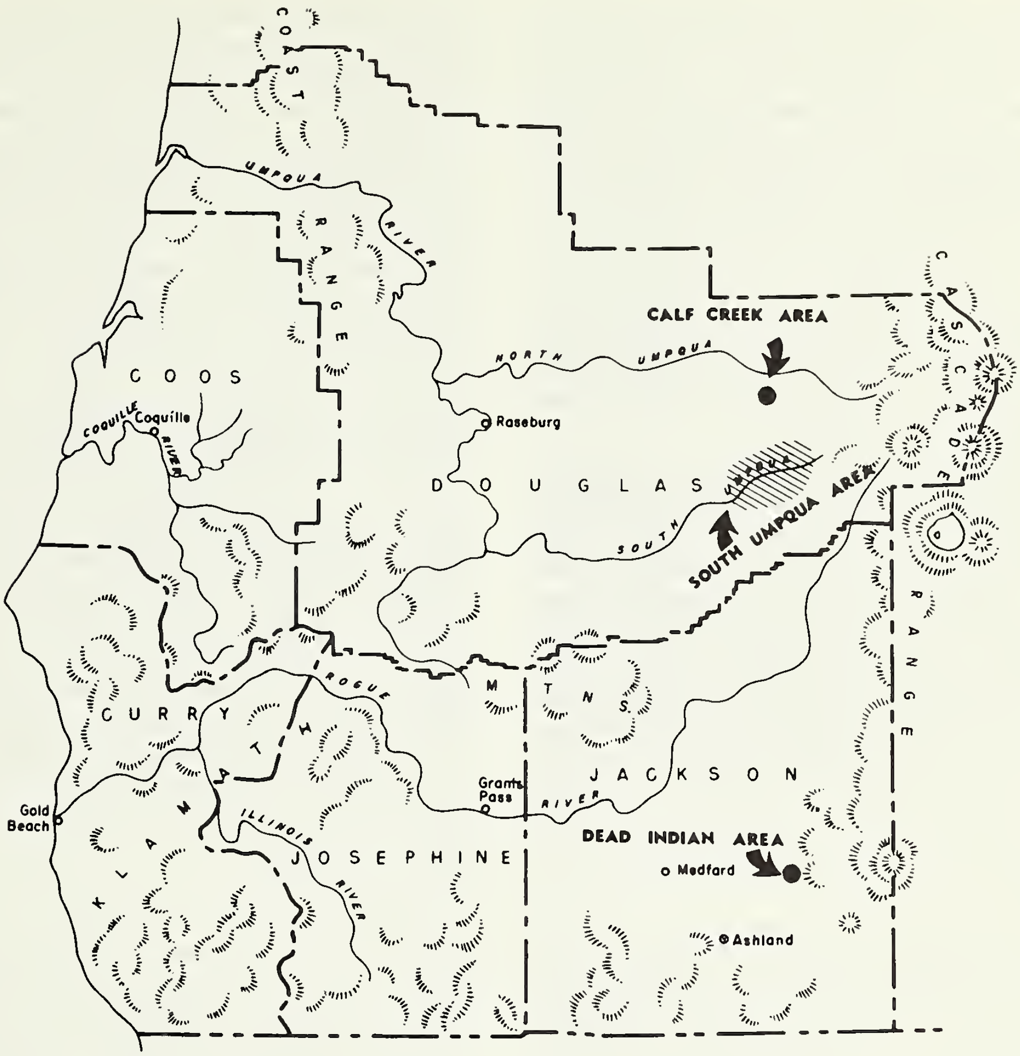


Figure 1. — Location of study areas.

to 20 percent. Vegetation coverage was estimated to the closest 10 percent on the basis of projection of live plant tissue to ground surface. Plant cover varied from 20 to 50 percent, with 30 percent being most prevalent. Although the percentages are low to medium, the vegetative cover density was subjectively considered medium to heavy. The more common plants[3] in order of abundance were: modest whipplea (*Whipplea modesta*), grass sp., grapeleaf California dewberry (*Rubus ursinus* var. *vitifolius*), salal (*Gaultheria shallon*) sedge (*Carex* spp.), Oregongrape (*Mahonia aquifolium*), western bracken (*Pteridium aquilinum* var. *pubescens*).

Soil derived from basaltic parent material is included in the tentative Coyota series, on steep slopes having both north and south aspects, and in the tentative Freezeout series on areas with level aspect.[4] Parent material at one north and one south aspect location was andesitic instead of basaltic. Coyota series are well-drained, medium-textured lithosols and intergrade to reddish-brown lateritic soils

[3] *Plant names from Kelsey and Dayton (1942).*

[4] *See footnote 2.*

developed from basic igneous parent material. The Freezeout series consists of well-drained, moderately fine-textured reddish-brown lateritic soils, also developed from basic igneous material. Soils derived from rhyolitic parent material are classed in the tentative Vena series on steep slopes and in the tentative Acker series on gentle to level areas. The Vena series are dark-brown or grayish-brown, well-drained, medium-textured lithosolic soils developed from acid igneous rock. The Acker series are well-drained, medium-textured, gray-brown Podzolic-like soils developed from acid igneous parent material.

Dead Indian. — The third area is a large cutover known locally as the Dead Indian area, northeast of Ashland in the Rogue River drainage at 122°20′ longitude and 42°18′ latitude. Three locations in a triangle approximately 20 to 25 chains on a side were selected on a gently sloping west-facing plateau. The slope is 5 to 15 percent at the sampling locations. The soil is a stony loam derived from andesitic parent material probably in the tentative Boze series.[5] The Boze series are brown, well-drained, medium-textured lithosolic soils developed from intermediate, igneous rock.

The purpose of this study was to determine whether moisture depletion by vegetation was great enough to be a factor in planted tree mortality. At each of the three locations, three points 15 to 25 feet apart were selected for a total of nine sampling points. Around one point, vegetation was removed with a hoe or mattock on an area about 10 feet square. Through the second point, a furrow 8 to 12 inches deep was made with a tractor-pulled plow. At the third point, the vegetation was left undisturbed. The vegetation was primarily grass species with a coverage of 20 to 30 percent.

Sample Collection

Two soil samples from each sampling position were collected — one for determination of moisture content and larger bulk sample for moisture tension and texture determinations. Samples were collected from a zone 4 inches thick, centering on 6-inch, 18-inch, and 36-inch depths, except in South Umpqua area where the lower depth was 28 inches because of shallow soil on steeper slopes. Moisture determination samples were a composite from three sides of a pit approximately 1 foot wide. Samples were put in metal cans, sealed with masking tape, weighed the following morning. Moisture content was determined gravimetrically. For the South Umpqua and Dead Indian areas, gravel, cobbles, and stones estimated to be over one-quarter inch were picked out and discarded when the samples for field moisture content were collected. However, bulk samples at South Umpqua and Dead Indian areas included all material — gravel, cobbles, stones, and soil — within the boundaries of the sample excavation in order that percent of material over one-quarter inch could be estimated. Bulk sample size varied from 1,000 to 1,500 grams air-dry weight for South Umpqua area and 3,000 to 18,000 grams for Dead Indian area. The Dead Indian samples were larger because of large stones. Calf Creek soil was relatively free of cobbles and stones, and no attempt was made to estimate cobble and stone content.

Both field moisture and bulk soil samples from Dead Indian area were collected the last week in July 1965, and from South Umpqua the first week in August 1965. Bulk samples and undisturbed cores in 100-cubic-centimeter lucite rings were collected from Calf Creek in October 1964.

Laboratory Analysis and Computations

Soil moisture at 1, 0.5, and 0.2 atmosphere of tension was determined for half of the undisturbed core samples from the Calf Creek area by the Oregon State University soils laboratory. Soil moisture retained at 3, 8, 15, and 25 atmospheres of tension was determined for soil from the bulk samples with pressure membrane apparatus (Richards 1947) for each sampling position at all sample points.

Equations for estimating soil moisture tensions from measured field moisture content were desired. However, with the equipment

[5] *See footnote 2.*

available (pressure membrane apparatus), tensions at which selected soil moisture contents are held cannot be determined. Rather, retained moisture for selected tensions must be determined. Thus, as selected tensions have no error, they must be used as an independent variable in regression analysis (Winsor 1946).

Therefore, it was necessary to calculate first for each sample a linear regression with the following equation:

$$\text{Log } y = A + B \log x$$

where

A and B = regression constants

y = soil moisture percent ovendry basis

and

x = atmospheres of tension.

Natural or Naperian logarithms were used. Then, the equations were reversed into the form

$$\text{Log } x = \frac{1}{B} \log y - \frac{A}{B}$$

and the soil moisture tension at the dry point of the summer was computed for each of the South Umpqua and Dead Indian samples.

Gravel particles, 2 mm. to ¼ inch, were left in samples for gravimetric moisture determination and for soil moisture retention determination in pressure membrane apparatus. These gravel particles were included because they contain or are associated with substantial amounts of moisture; also, they helped to avoid crushing soil aggregates 2 mm. to ¼ inch in size.

Percentage of (1) stones, cobbles, and medium and coarse gravel over one-quarter inch in size, and (2) fine gravel, 2 mm. to ¼ inch, was determined by screening and weighing when air dry. Particle-size distributions into sand, silt, and clay (6-hour settling) were made by the hydrometer method (Day 1956). Although particles over 2 mm. were screened out of samples used for texture analysis by the hydrometer method, final figures on particle size were recomputed to include fine gravel, 2 mm. to ¼ inch, because fine gravel was included in samples used for determination of moisture retention over tension and for field moisture content.

RESULTS

Texture

Rhyolitic soils were coarser textured than basaltic soils (tables 1, 2, 3). Rhyolitic soils contain, on the average, more stones, cobbles, gravel, and sand, whereas basaltic soils contain more silt and clay. However, the difference in clay content is not statistically significant (table 3). The Calf Creek soils (basaltic) are very similar in texture to basaltic soils found on level ground in South Umpqua (table 4). Texture of South Umpqua basaltic soils on north and level aspects is quite similar, whereas soils on south aspects are coarser. Rhyolitic soils on north aspect in the South Umpqua have similar texture to those on south aspect, but soils on level aspects are finer textured. Clay content for all soils sampled increased and sand decreased with depth (tables 1 and 3). The most consistent relationship was the larger amounts of silt for basaltic than for rhyolitic soils (tables 1, 2, 3).

Particle-size distribution varied greatly for any one depth, aspect, and soil (tables 2,4). Even on the Calf Creek area, covering less than 2 acres, the variation was quite evident. Occasionally, particle-size distribution differed greatly in two samples obtained only 10 feet apart. For example, in one pair of sampling points, clay content was 20 percent at one point and 47 percent for the other at the 28-inch depth; in another pair, gravel content was 23 percent at one point and 51 percent at the other at the 6-inch depth.

TABLE 1. – Particle-size distribution for South Umpqua samples – means[1] of six samples
(In percent)

BASALT AND ANDESITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Coyota series)			
6	9.8	30.7 (34.0)	38.5 (42.5)	21.0 (23.5)	14.6
18	5.8	22.8 (24.5)	40.8 (43.3)	30.5 (32.2)	21.4
28	6.8	19.8 (21.7)	36.7 (39.3)	36.7 (39.0)	14.3
		South aspect (Coyota series)			
6	18.3	34.3 (43.2)	27.8 (33.8)	19.5 (23.0)	46.5
18	15.5	33.0 (40.5)	29.2 (33.7)	22.3 (25.8)	36.8
28	17.3	34.2 (43.2)	27.3 (32.3)	21.2 (24.5)	37.7
		Level (Freezeout series)			
6	11.8	32.3 (36.5)	34.5 (39.0)	21.3 (24.5)	1.2
18	4.5	25.0 (26.0)	36.3 (38.2)	34.2 (35.8)	1.0
28	2.8	24.6 (25.4)	32.3 (33.3)	40.2 (41.3)	10.8
		All aspects			
6	13.3	32.4 (37.9)	33.6 (38.4)	20.6 (23.7)	20.8
18	8.6	26.9 (30.3)	35.4 (38.4)	29.0 (31.3)	19.8
28	9.0	26.2 (30.1)	32.1 (35.0)	32.7 (34.9)	20.9

RHYOLITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Vena series)			
6	23.8	36.5 (48.0)	20.0 (26.2)	19.7 (25.8)	35.3
18	37.3	33.5 (54.2)	12.5 (20.0)	16.3 (25.8)	60.0
28	38.3	31.3 (51.2)	11.5 (18.8)	18.3 (30.0)	54.8
		South aspect (Vena series)			
6	26.0	40.8 (56.1)	17.8 (23.7)	15.3 (20.2)	36.7
18	22.0	38.3 (49.7)	19.5 (24.7)	20.2 (25.6)	56.3
28	29.2	35.3 (51.0)	15.5 (21.7)	20.0 (27.3)	63.3
		Level (Acker series)			
6	16.2	32.7 (39.5)	29.5 (35.0)	21.7 (25.5)	16.7
18	8.3	28.2 (30.6)	31.7 (34.7)	31.8 (34.7)	12.4
28	8.5	27.2 (29.8)	31.0 (34.2)	33.3 (36.0)	14.8
		All aspects			
6	22.0	36.7 (47.9)	22.4 (28.3)	18.9 (23.8)	29.6
18	22.7	33.3 (44.8)	21.2 (26.5)	22.8 (28.7)	42.9
28	25.3	31.3 (44.0)	19.3 (24.9)	24.0 (31.1)	44.3

[1] *Percentages of particles over ¼ inch are for total sample but are excluded from sample for other particle-size percentages.*
Particles over 2 mm. are excluded from total for figures in parentheses.

TABLE 2. – Particle size[1] distribution for South Umpqua samples – range[2]
(In percent)

BASALT AND ANDESITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Coyota series)			
6	4-17	25-38	26-46	16-25	7-49
18	2-10	14-32	32-46	20-50	1-74
28	2-14	8-33	29-44	20-56	0-33
		South aspect (Coyota series)			
6	6-48	29-42	14-37	8-30	16-67
18	6-32	24-39	18-38	13-32	7-68
28	3-39	28-43	15-38	9-33	8-66
		Level (Freezeout series)			
6	1-20	27-37	27-41	18-26	0-2
18	0-11	20-29	32-43	23-43	0-2
28	0-8	21-29	24-42	33-48	0-43
		All aspects			
6	1-48	25-42	14-46	8-30	0-67
18	0-32	14-39	18-46	13-50	0-74
28	0-39	8-43	15-44	9-56	0-66

RHYOLITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Vena series)			
6	20-31	29-48	16-29	11-32	18-55
18	33-47	29-40	9-17	11-23	49-74
28	29-52	26-37	8-16	9-25	34-65
		South aspect (Vena series)			
6	11-51	29-42	11-27	9-25	18-61
18	17-31	31-45	14-24	10-33	10-85
28	17-39	28-42	9-20	10-36	20-90
		Level (Acker series)			
6	2-25	31-37	25-33	17-32	0-37
18	2-15	26-29	28-34	27-37	0-25
28	2-15	22-37	28-32	20-40	0-33
		All aspects			
6	2-51	29-48	25-33	9-32	0-61
18	2-47	26-45	9-34	10-37	0-85
28	2-52	22-42	8-32	10-40	0-90

[1] *Percentages of particles over ¼ inch are for total sample – particles over ¼ inch excluded from sample for other particle-size percentages.*
[2] *6 samples for each range.*

TABLE 3. – F values for particle size,[1] South Umpqua samples

Source	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
Aspect	4.61*	6.78*	4.61*	(2)	6.98**
Soil	11.76**	7.78*	29.49**	(2)	5.14*
Aspect x soil	(2)	(2)	5.17*	(2)	(2)
Depth	(2)	8.54**	4.95*	17.02**	(2)
Depth x aspect	7.92**	(2)	(2)	3.21*	(2)
Depth x soil	5.60**	(2)	(2)	(2)	3.59*
Depth x aspect x soil	3.96**	(2)	(2)	(2)	(2)

[1] *Separate analysis for each particle size.*

[2] *Nonsignificant.*

* *Significant at 5-percent level.*
***Significant at 1-percent level.*

TABLE 4. – Particle-size distribution for Calf Creek samples, Freezeout soil series

(In percent)

Particle size	Means for 24 samples[1]			Range for 24 samples		
	6-inch depth	18-inch depth	36-inch depth	6-inch depth	18-inch depth	36-inch depth
2mm. to ¼ inch	9.9	5.2	3.2	2-22	1-13	0-11
Sand	29.6 (32.9)	26.1 (27.6)	22.0 (22.6)	23-34	17-31	10-34
Silt	39.4 (43.7)	42.3 (44.7)	39.2 (40.7)	33-48	36-48	30-45
Clay	21.1 (23.4)	26.4 (27.7)	35.6 (36.7)	15-32	21-36	22-56

[1] *Figures in parentheses: particles over 2 mm. excluded from total.*

Hallin, William E.
1968. Soil moisture tension variation on cutovers in southwestern Oregon. U. S. Forest Serv. Res. Pap. PNW-58, 18 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Estimating soil moisture tension from soil moisture content, growth, effect of silvicultural treatment on growth and response, and some positive steps to improve success of planting or seeding are presented.

Hallin, William E.
1968. Soil moisture tension variation on cutovers in southwestern Oregon. U. S. Forest Serv. Res. Pap. PNW-58, 18 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Estimating soil moisture tension from soil moisture content, growth, effect of silvicultural treatment on growth and response, and some positive steps to improve success of planting or seeding are presented.

Hallin, William E.
1968. Soil moisture tension variation on cutovers in southwestern Oregon. U. S. Forest Serv. Res. Pap. PNW-58, 18 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Estimating soil moisture tension from soil moisture content, growth, effect of silvicultural treatment on growth and response, and some positive steps to improve success of planting or seeding are presented.

Hallin, William E.
1968. Soil moisture tension variation on cutovers in southwestern Oregon. U. S. Forest Serv. Res. Pap. PNW-58, 18 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Estimating soil moisture tension from soil moisture content, growth, effect of silvicultural treatment on growth and response, and some positive steps to improve success of planting or seeding are presented.

Soil Moisture Tension

Soil Moisture Retention Curves

The calculated soil moisture retention curves (log soil moisture = A + B log tension in atmospheres) fit the data very well for the range 3 to 25 atmospheres of tension (figs. 2, 3, 4, 5, 6). Not a single one of 816 individual computed points deviated over 1 percent in soil moisture content from the measured value.

Data from Calf Creek show that soil moisture retained at tensions of 1 atmosphere and lower is less than would be expected from extrapolation of the linear logarithmic regressions computed for the range of 3 to 25 atmospheres.

Soil moisture at 0.2, 0.5, and 1.0 atmosphere for undisturbed samples from Calf Creek averaged 79.6, 88.2, and 96.3 percent,

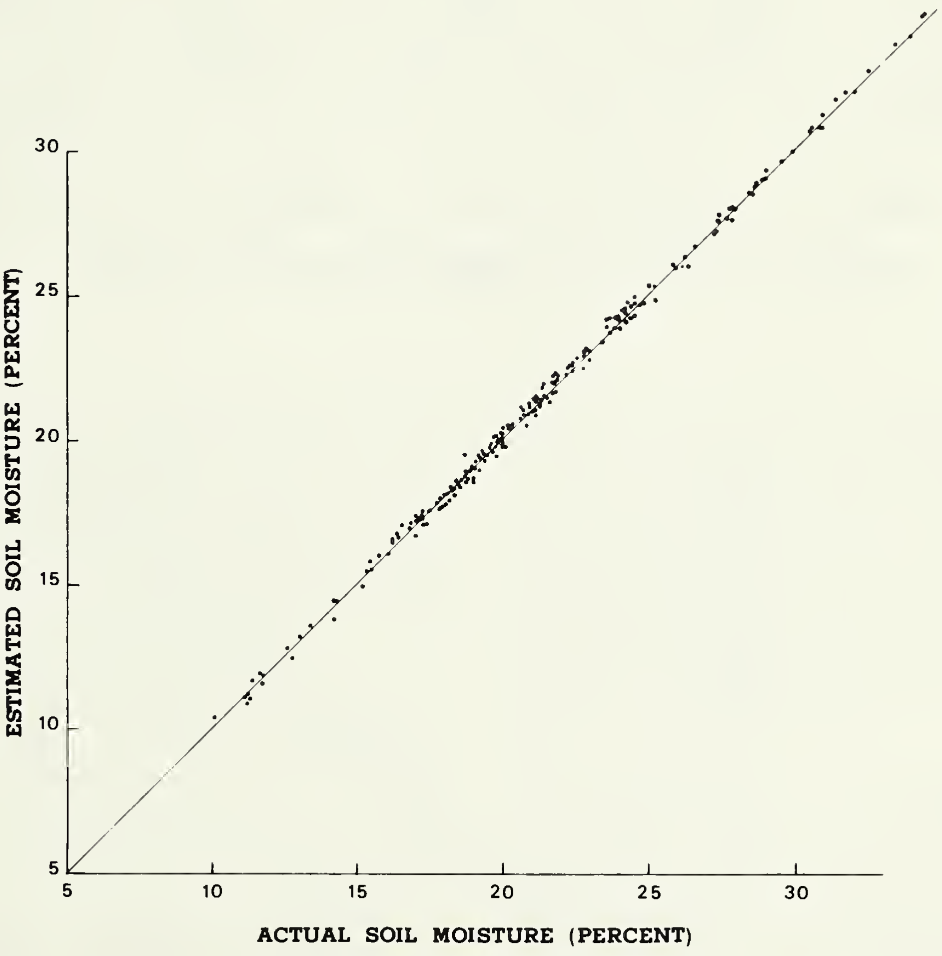


Figure 2. – Comparison of estimated and actual soil moisture percentages at 3 atmospheres for logarithmic soil moisture retention curves.

Figure 3. — Comparison of estimated and actual soil moisture percentages at 8 atmospheres for logarithmic soil moisture retention curves.

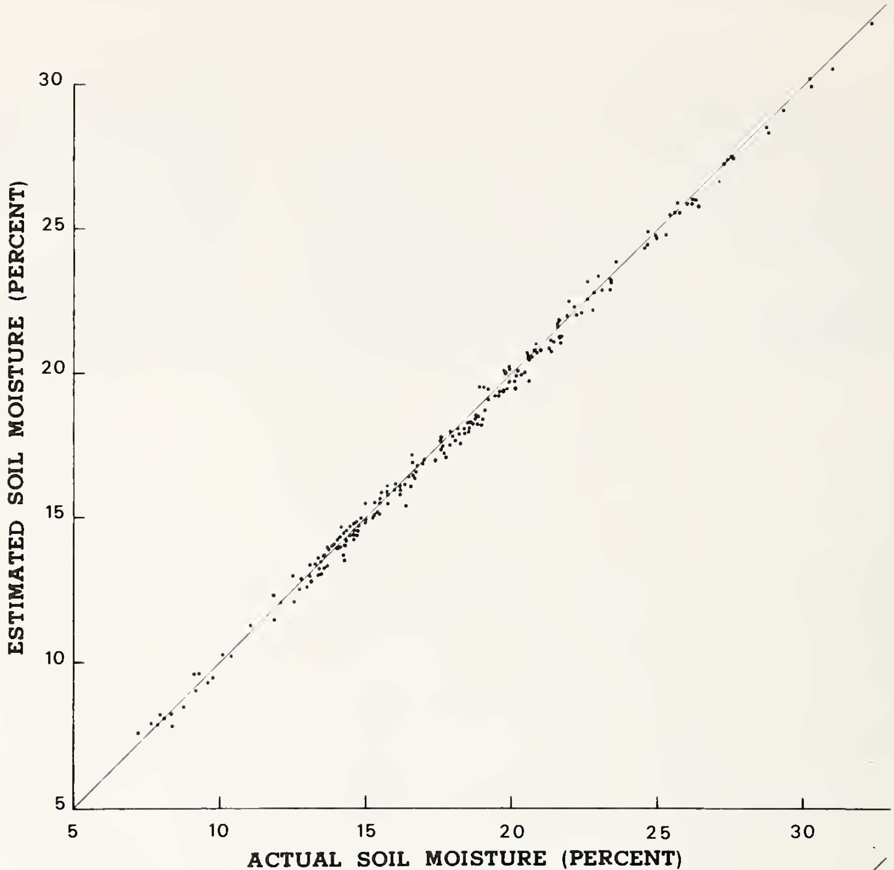
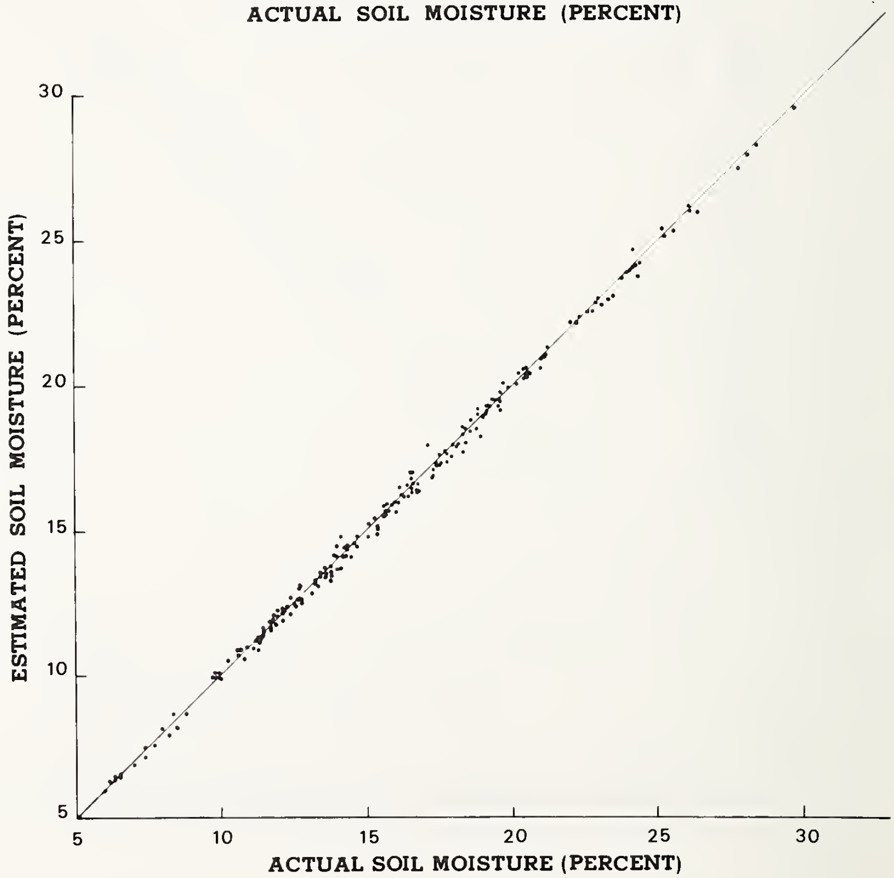


Figure 4. — Comparison of estimated and actual soil moisture percentages at 15 atmospheres for logarithmic soil moisture retention curves.



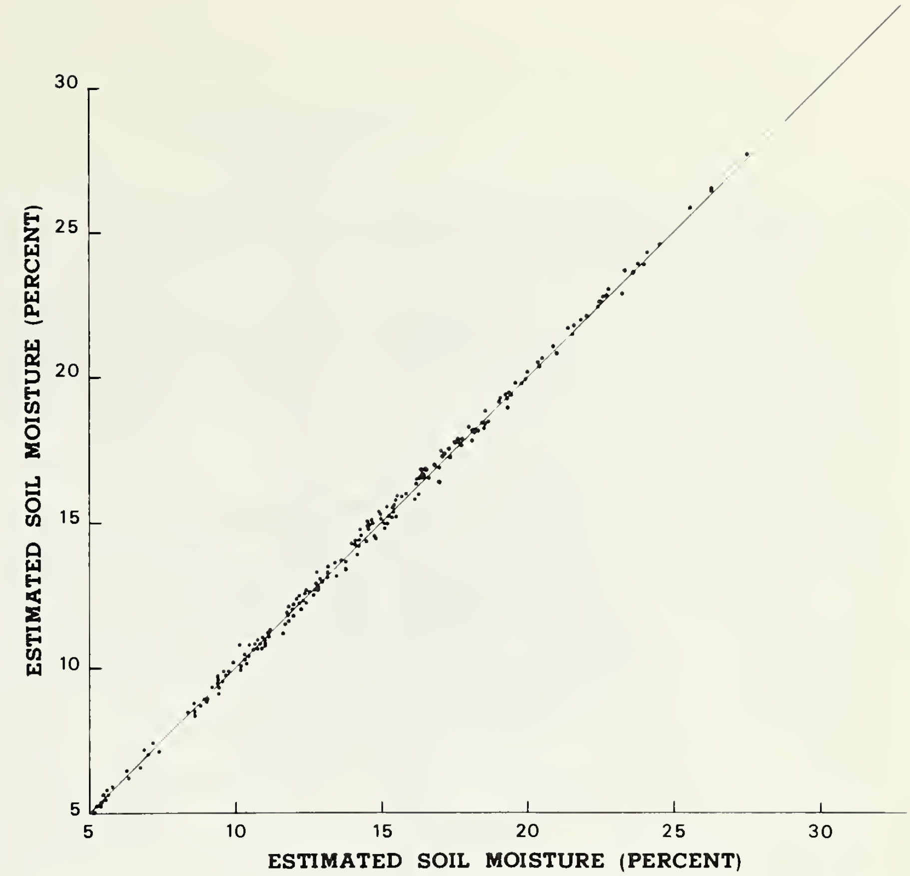


Figure 5. – Comparison of estimated and actual soil moisture percentages at 25 atmospheres for logarithmic soil moisture retention curves.

respectively, of the estimated values as computed from extrapolations of the 3- to 25-atmosphere soil moisture retention curves. However, percentages for individual samples varied greatly from these averages. For example, for 0.2 atmosphere of tension they ranged from 65.3 to 100.2 percent.

Soil Moisture at 15 Atmospheres

Soil moisture at 15 atmospheres of tension varied greatly — ranging from 10.0 to 29.7 percent for basaltic soil, and 6.0 to 21.2 for rhyolitic soil (table 5).

At Calf Creek, means and ranges were as follows:

Depth	Means	Range
(Inches)	(Percent)	(Percent)
6	13.2	11.0 to 18.2
18	14.7	12.1 to 21.2
36	18.9	15.4 to 25.2

The difference between the means for basaltic soil, 19.2, and rhyolitic soil, 12.6, was significant at the 5-percent level. At Calf Creek, soil moisture at 15 atmospheres increased with soil depth at every sampling point. At the South Umpqua area, there were a number of sampling points for basaltic and rhyolitic soils for which soil moisture at 15 atmospheres was approximately the same for all three depths. However, the average trend was increasing moisture content with increasing depth, and differences were significant at the 1-percent level.

The differences in soil moisture content at 15 atmospheres between points 10 feet apart varied from 0 to 7.9 percent of soil moisture and was greatest at the deepest depth (table 6). For example, at the maximum difference of 7.9 percent, the soil moisture content at one point was 18.3 percent and 26.2 percent at the other point.

Soil moisture level at 15 atmospheres tends to increase with increasing clay content (fig. 7). However, the spread of values is quite large.

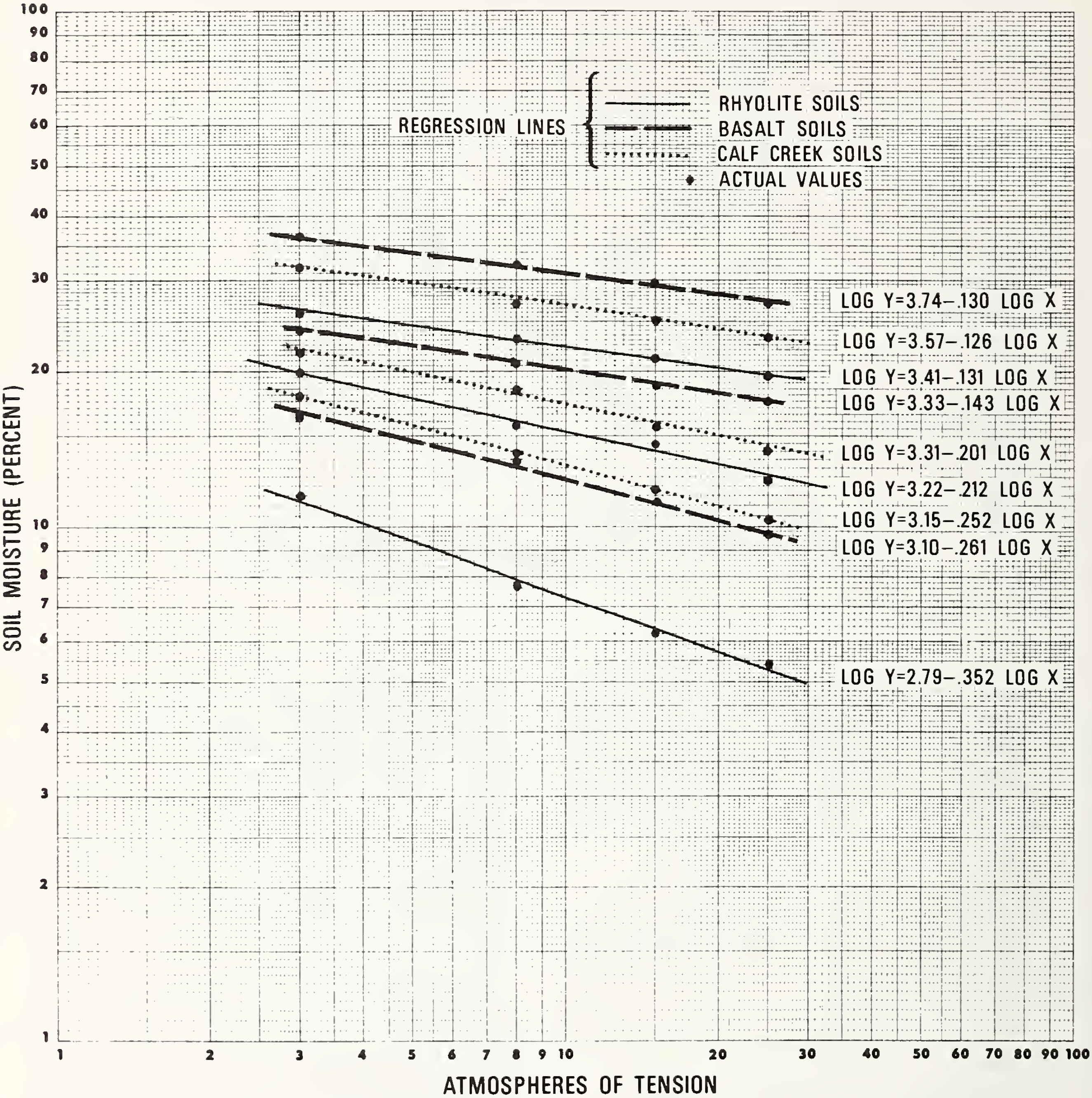


Figure 6. – Typical moisture retention curves (each regression line for a single sampling point and depth).

TABLE 5. – Soil moisture at 15 atmospheres of tension for basaltic and rhyolitic soils[1]
South Umpqua area
(In percent)

Depth (inches)	North aspect		South aspect		Level		All aspects	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
BASALT								
6	15.0	10.9-18.3	18.8	11.6-25.2	18.4	13.9-22.3	17.4	10.9-25.2
18	17.6	10.6-24.1	19.0	11.1-24.4	21.1	16.3-28.4	19.2	10.6-28.4
28	20.1	11.2-28.1	19.3	10.0-26.4	23.3	20.5-29.7	20.9	10.0-29.7
A11	17.6	10.6-28.1	19.1	10.0-26.4	21.0	13.9-29.7	19.2	10.0-29.7
RHYOLITE								
6	15.1	6.3-20.4	8.2	6.0-11.2	11.4	9.8-16.0	11.6	6.0-20.4
18	14.8	6.4-20.4	9.5	6.6-13.8	13.8	9.8-17.5	12.7	6.4-20.4
28	15.8	8.5-21.2	10.1	6.5-14.4	14.5	11.2-18.1	13.5	6.5-21.2
A11	15.2	6.3-21.2	9.2	6.0-14.4	13.2	9.8-18.1	12.6	6.0-21.2

[1] *Each mean and range (except for "A11 aspects") based on 6 samples.*

Soil Moisture Tension Attained With and Without Vegetation

Vegetation very markedly depleted soil moisture during the summer. Soil moisture tensions reached at the dry point in the summer on the South Umpqua study area were many times higher on plots with vegetation than without at all soil depths (table 7). On 16 of the 18 plots with vegetation, the soil moisture tensions reached 15 atmospheres or more at the 6-inch depth; and at all depths at all locations, soil moisture tensions were several times greater for plots with than without vegetation.

Soil moisture tension reached on vegetated plots was much greater on south exposures than on north. On five of the six south exposure plots, tension was over 40 atmospheres at the 6-inch depth. Soil moisture tension decreased with depth at all sampling points.

Soil moisture tensions at 6 inches were greater at Dead Indian area than at South Umpqua for plots with vegetation (table 8). At the lower depths, tensions were less at Dead Indian area than at South Umpqua. The short time interval between collection of Dead Indian and South Umpqua samples should be of little concern as soil moisture content is changing very slowly in late July and early August (Hallin 1967).

TABLE 6. – Differences in soil moisture percent at 15 atmospheres of tension for points 10 feet apart

(In percent)

Depth (inches)	Basalt		Rhyolite	
	Means	Range	Means	Range
6	0.8	0.1 - 1.4	1.4	0.2 - 5.4
18	1.5	.3 - 3.3	1.4	0 - 3.0
28	2.3	0 - 7.9	2.8	.3 - 6.0

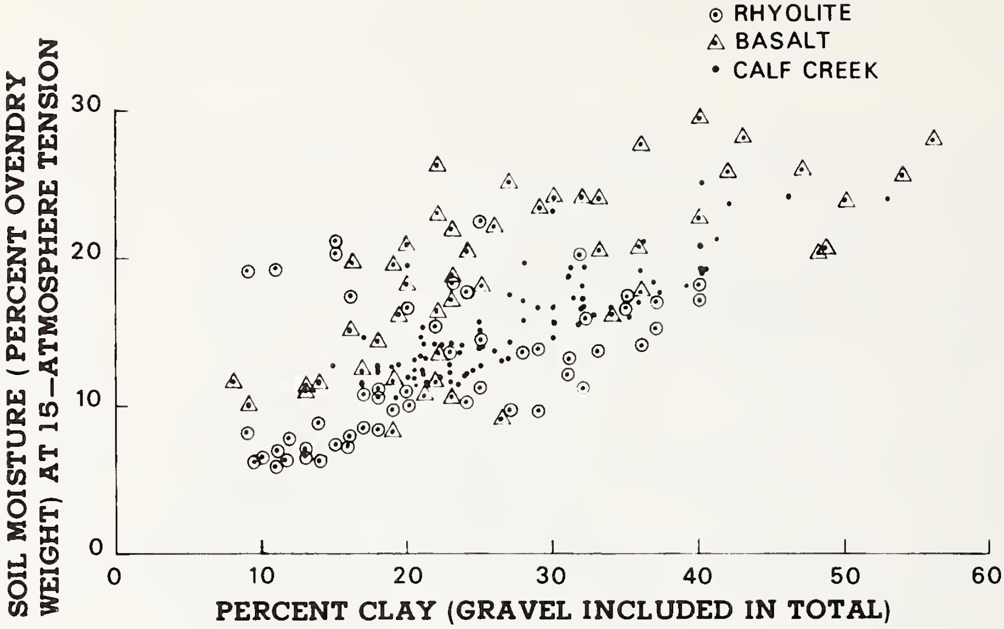


Figure 7. — Soil moisture at 15 -atmosphere tension and clay content.

TABLE 7. – Soil moisture tension for basaltic and rhyolitic soils with and without vegetation at the approximate summer dry point,[1] South Umpqua area (means for three samples)

BASALTIC SOIL

Depth (inches)	North aspect		South aspect		Level aspect		All aspects	
	With vegetation	Without vegetation	With vegetation	Without vegetation	With vegetation	Without vegetation	With vegetation	Without vegetation
	Atmospheres							
6	23.2	2.7	53.5	13.1	22.2	2.7	33.0	6.1
18	12.7	1.2	13.9	1.9	9.5	1.0	12.0	1.4
28	6.0	1.1	8.7	.9	3.4	.6	6.0	.9
All	14.0	1.6	25.3	5.3	11.7	1.4	17.0	2.8

RHYOLITIC SOIL

Depth (inches)	North aspect, with vegetation	North aspect, without vegetation	South aspect, with vegetation	South aspect, without vegetation	Level aspect, with vegetation	Level aspect, without vegetation	All aspects, with vegetation	All aspects, without vegetation
6	17.9	5.4	85.0	6.3	25.1	3.6	42.7	5.1
18	9.8	1.8	31.1	4.3	10.0	2.4	17.0	2.8
28	5.3	1.4	20.2	2.8	7.6	1.6	11.1	2.0
All	11.0	2.9	45.4	4.5	14.2	2.6	23.6	3.3

[1] *1st week in August 1965.*

TABLE 8. – Soil moisture tension at Dead Indian area for plots with vegetation, without vegetation, and with furrow at the approximate summer dry point[1] (means for three samples)

Depth (inches)	With vegetation	Without vegetation	Furrow[2]
	Atmospheres		
6	101.7	1.0	0.9
18	3.4	.5	.5
36	.6	.4	([3])

[1] *Last week in July 1965.*
[2] *Furrows 10 to 12 inches deep – depth measured from bottom of furrow.*
[3] *No sample at 36 inches.*

DISCUSSION AND CONCLUSIONS

Some results reported here may differ from those usually obtained because fine gravel (2 mm. to ¼ inch) has been included in samples for field moisture content, moisture retention over tension, and particle size distribution determination. Fine gravel was included because it holds or is associated with soil moisture and because soil aggregates would have been eliminated or crushed if soil particles between 2 mm. and ¼ inch had been screened out.

Although rhyolitic soil was distinctly coarser textured than basaltic soil, the large range and overlap in particle size between soils developed on these two parent materials are perhaps even more important. The high variation found at Calf Creek on an area of less than 2 acres and sometimes between points only 10 feet apart on the South Umpqua area emphasizes the conclusion that there is great variation in particle size distribution within the tentative soil series sampled. Sampling by soil horizons instead of fixed depths probably would have reduced the variation in particle size distribution somewhat, but not enough to alter the conclusion that there is large variation in texture within the tentative soil series sampled. Although there were trends in particle size distribution with depth, differences in texture between adjoining depth classes at a sampling point usually were not large. Furthermore, it is likely that a high percentage of samples from a given depth, aspect, and soil series would have come from the same soil horizon.

When tree growth and response to treatment are considered, the wide range in particle size distribution and in soil moisture at 15 atmospheres of tension for the soil series studied suggests the following questions: (1) Is particle size distribution more important than parent material? (2) Is coarse-textured basaltic soil more like rhyolitic soil than typical basaltic soil, or does the parent material

impart other characteristics that overshadow the effect of texture? These and other questions that might be asked suggest that much more research is needed to determine what soil characteristics are important to tree growth and how these characteristics affect growth and respond to treatment. This information is needed in order to establish better criteria for classifying forest soils and to aid in improving management of forest land in southwestern Oregon.

As shown by the scatter diagrams of estimated over actual values, the linear logarithmic soil moisture retention equations (log soil moisture = A + B log tension) fit the data for each sample quite closely for each of the tensions (3, 8, 15, and 25 atmospheres) used in the regression analysis. Consequently, the inverted form (log of tension = $\frac{1}{B}$ log soil moisture - $\frac{A}{B}$) of these linear logarithmic equations is suitable for computing soil moisture tension from field moisture content for the soils studied through at least the range of 3 to 25 atmospheres and is likely to be appropriate for many similar soils.

Undisturbed soil samples or cores are needed to measure soil moisture retention for low tensions — 1 atmosphere and lower — as soil structure affects soil moisture retention at low tensions. Undisturbed cores are difficult or impossible to get in cobbly or stony soils. Furthermore, several cores may be needed to arrive at a meaningful average value for a given location. Consequently, it would be highly desirable to be able to accurately extrapolate the regression for moisture values of disturbed samples in the 3- to 25-atmosphere range in order to estimate values for tensions below 1 atmosphere. The data obtained from the Calf Creek soil cores show that actual soil moisture content for 1 atmosphere and lower is below values extrapolated from the regression equations for tensions ranging 3 to 25 atmospheres. This is not surprising when the nature of a logarithmic curve is considered. Theoretically, there should be a maximum soil moisture content when "0" tension is reached; however, there would be no maximum with a logarithmic curve because it approaches but never reaches zero. Plotting on double logarithmic paper shows that the regression for 3 to 25 atmospheres intersects the plotted line for low tensions at approximately 1½ atmospheres.

The variability in the relationship between soil moisture at low tensions for undisturbed Calf Creek samples and extrapolated values from equations for tensions ranging from 3 to 25 atmospheres may be due to lack of comparability of the samples. At each sampling point, only one undisturbed core was obtained, whereas the bulk sample was a composite of several samples spread over about 1 or 2 square feet. Perhaps additional research in which special care is taken to insure comparability of disturbed and undisturbed samples will uncover means by which soil moisture at low tensions can be estimated from extrapolated values for equations developed for higher tensions.

Other researchers (Nielsen and Shaw 1958) have shown that, for many soils, percentage of clay can be used for accurately estimating soil moisture at 15 atmospheres of tension. Although a relationship between soil moisture at 15 atmospheres and clay content was found for the Calf Creek and South Umpqua areas, the scatter of the data is much too great for accurate estimation of soil moisture content at 15 atmospheres from a single overall regression with percentage of clay.

Undoubtedly, the spread in the data would be less if fine gravel had been excluded from samples used for both soil moisture and texture determination. For small areas such as Calf Creek, or small groups of plots from the South Umpqua area, soil moisture at 15 atmospheres could be accurately estimated from percentage of clay. However, regressions would have to be tested for each relatively small area for which estimating equations are desired, and direct measurements of soil moisture at 15 atmospheres would undoubtedly be more economical.

Large differences in soil moisture retention at 15 atmospheres for points 10 feet apart indicate that samples for determining soil moisture retention curves should be taken as close as possible to the point where samples will be collected for soil moisture determination.

The much higher soil moisture tensions on plots with vegetation than on those without

vegetation show the importance of vegetation in depleting soil moisture. Competing vegetation clearly is an important cause of new regeneration mortality. Soil moisture tensions during the dry period of the summer were 15 atmospheres (the permanent wilting point) or higher at the 6-inch depth for 19 out of the 21 locations with vegetation.

Obviously then, positive steps to counteract the moisture drain of competing vegetation must be taken in order to insure successful establishment of regeneration. Some possibilities are: (1) establishing regeneration promptly after harvest cutting before competing vegetation is fully established, and (2) controlling vegetation if and when present.

As soil moisture tension decreases with depth at all sampling points, use of planting stock with roots as long as can be economically planted is indicated.

SUMMARY

1. Although rhyolitic soils are coarser textured than basaltic soils, there was a wide range in particle size distribution within each group and considerable overlap between soils from the two parent materials.

2. Linear logarithmic regressions of the form "log soil moisture = A + B log tension" fit data from basaltic, rhyolitic, and andesitic soils at three locations in southwestern Oregon between 3 and 25 atmospheres of tension. In inverted form, these can be used for estimating soil moisture tension from soil moisture content.

3. Measured soil moisture in undisturbed cores for tensions 1 atmosphere and less are lower than values extrapolated from the linear logarithmic moisture retention curves for disturbed soil samples based on tensions ranging 3 to 25 atmospheres.

4. Soil moisture percent at 15 atmospheres of tension varied greatly even within a relatively uniform area as small as 2 acres and frequently between points only 10 feet apart. Therefore, samples used for preparing soil moisture retention curves should be collected as close as possible to the point from which samples for moisture determination and subsequent moisture tensions are to be determined.

5. Additional basic soils research to define more clearly soil characteristics important to tree growth and to determine effect on growth and response to silvicultural treatment is suggested in order to improve criteria for forest soils classification and timber production.

6. Soil moisture tension at 6-inch depth during the driest period of the summer on cutover areas with vegetation is much higher than where vegetation has been removed — usually 15 to 25 atmospheres or more compared to 2 to 8 atmospheres where vegetation has been removed. Therefore, positive steps are needed, such as planting or seeding as soon as possible after harvest cutting before vegetation becomes fully established, or removing or killing part of established vegetation before attempting to establish regeneration.

LITERATURE CITED

Day, Paul R.
1956. Report of the Committee on Physical Analyses, 1954-55, Soil Science Society of America. Soil Sci. Soc. Amer. Proc. 20:167-169.

Hallin, William E.
1967. Soil-moisture and temperature trends in cutover and adjacent old-growth Douglas-fir timber. Pacific Northwest Forest & Range Exp. Sta. U. S. Forest Serv. Res. Note PNW-56, 11 pp., illus.

Kelsey, Harlan P., and Dayton, William A.
1942. Standardized plant names. Ed. 2, 675 pp. Harrisburg, Pa.: J. Horace McFarland Co.

Nielsen, D. R., and Shaw, R. H.
1958. Estimation of the 15-atmosphere moisture percentage from hydrometer data. Soil Sci. 86: 103-105, illus.

Richards, L. A.
1947. Pressure-membrane apparatus — construction and use. Agr. Eng. 28: 451-454 and 460, illus.

______________ and Weaver, L. R.
1943. Fifteen-atmosphere percentage as related to the permanent wilting percentage. Soil Sci. 56: 331-339, illus.

Shaw, B. T. (ed.)
1952. Soil physical conditions and plant growth. Joint Committee on Soil Tilth. 491 pp. New York: Academic Press.

Winsor, Charles P.
1946. Which regression? Biometrics Bull. 2:101-109, illus.

Zahner, Robert, and Whitmore, F. W.
1960. Early growth of radically thinned loblolly pine. J. Forest. 58: 628-634, illus.

Headquarters for the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is in Portland, Oregon. The area of research encompasses Alaska, Washington, and Oregon, with some projects including California, the Western States, or the Nation. Project headquarters are at:

College, Alaska
Jeneau, Alaska
Seattle, Washington
Olympia, Washington
Wenatchee, Washington
Portland, Oregon
Bend, Oregon
LaGrande, Oregon
Corvallis, Oregon
Roseburg, Oregon

The FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.